Ground System Survivability Overview

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Steve Knott
Associate Director
Ground System Survivability

Report Documentation Page

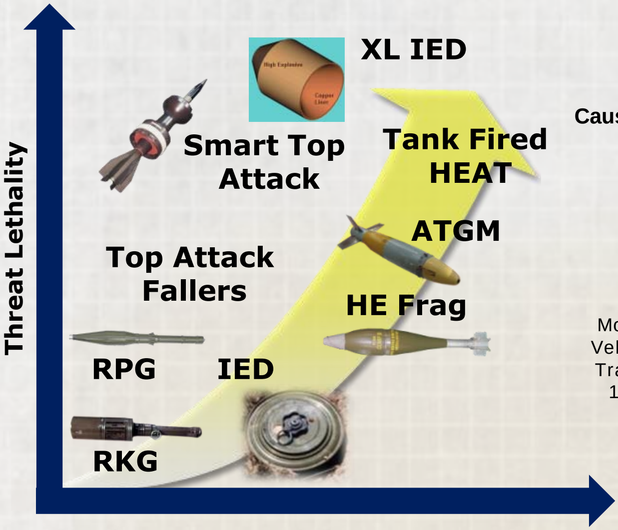
Form Approved
OMB No. 0704-0188

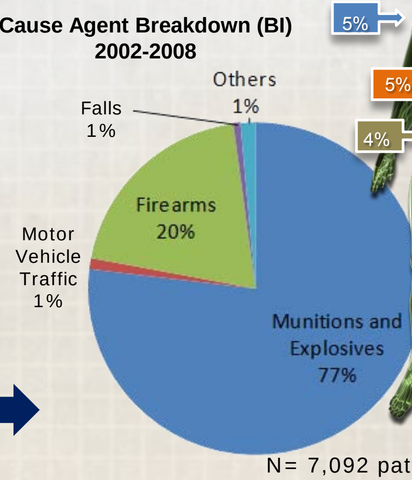
1. REPORT DATE **28 OCT 2010**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **Ground System Survivability Overview**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Steve Knott**		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA**		8. PERFORMING ORGANIZATION REPORT NUMBER **21299**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) **TACOM/TARDEC**
		11. SPONSOR/MONITOR'S REPORT NUMBER(S) **21299**
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release, distribution unlimited**		
13. SUPPLEMENTARY NOTES **The original document contains color images.**		
14. ABSTRACT		
15. SUBJECT TERMS		

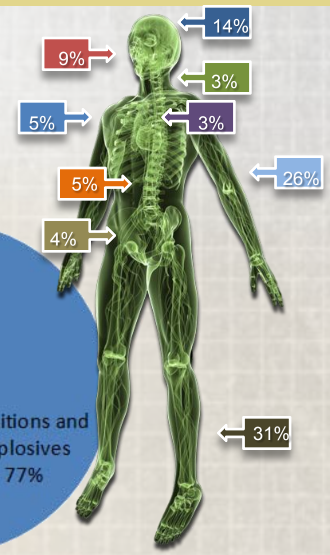
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**27**	

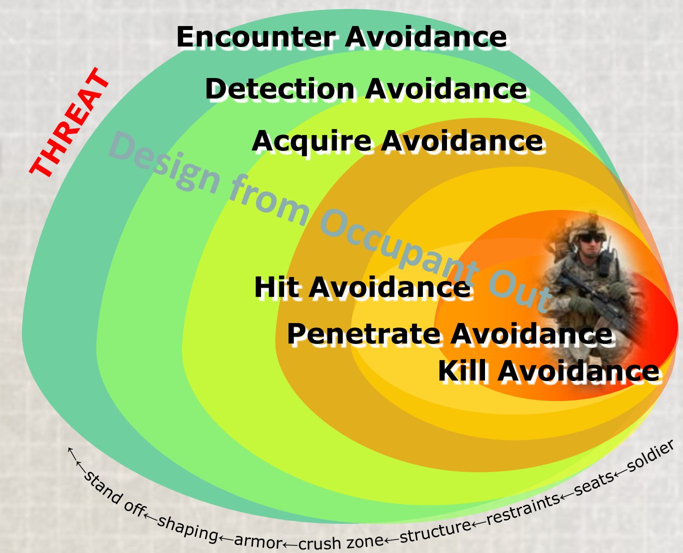
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Excellence in Ground Systems Survivability Occupant Centric Vehicle Protection



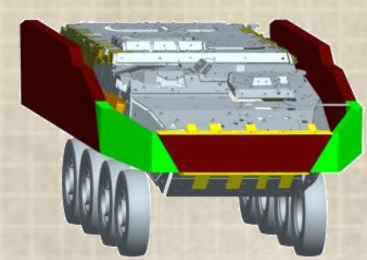






Increasing Demands and Operational Flexibility Require Strategic Investments in Key Areas

Kill Avoidance



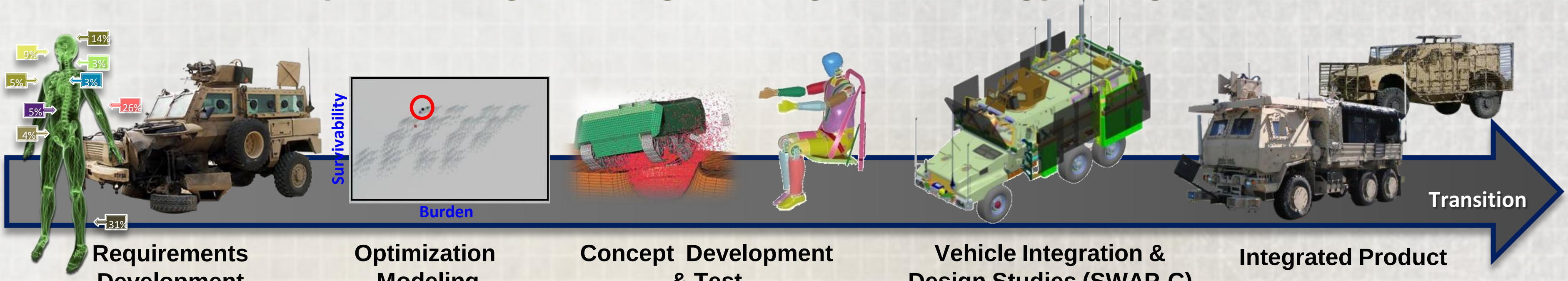
Penetration Avoidance

Hit Avoidance

Detection Avoidance

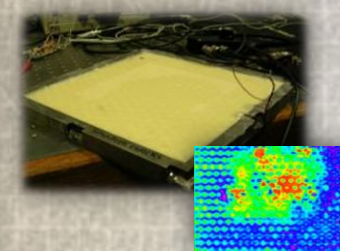
Excellence in Ground Systems Survivability Occupant Centric Vehicle Protection

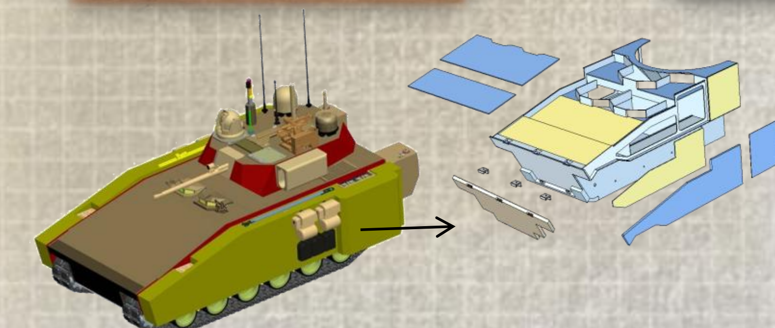
System Engineering Driving Technology Integration



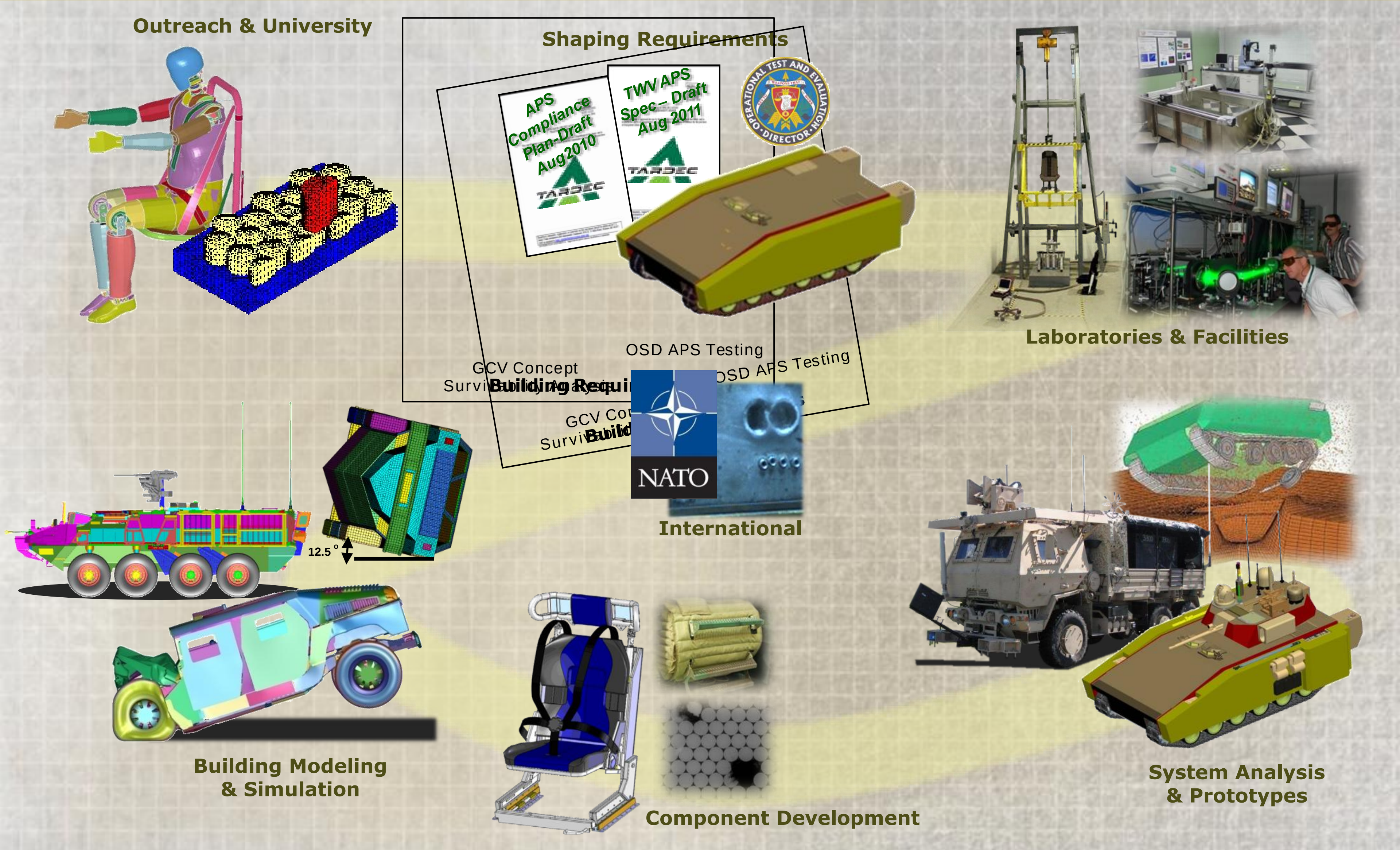
Supporting the Current Force

Enabling the Future Fight





Excellence in Ground Systems Survivability Occupant Centric Vehicle Protection



Driving Innovation across the Ground Community

- Novel, inventive vehicle design approaches
- Rapid acquisition (12-18 month timelines)
- Extensive use of M&S tools to optimize design
- Non-tradition defense project partners
- Embedded with ARCIC to drive requirements generation for future platform requirements

Project Weight Class	Project Objectives	Project Partners	Project Schedule
Heavy Combat **100,000 - 140,000 lbs**	• Soldier-Centric Vehicle Design • Modular, Reconfigurable Vehicle Systems • Targeting selected GCV Objective Requirements	RDECOM **ACT VI Project**	• 18-24 months for Multiple Concept Development
Medium Combat **40,000 - 60,000 lbs**	• S-MOD/MPC Threshold Survivability • Motor Sports Vehicle Design Process • M1 Equivalent Mobility	**Professional Motorsports Industry**	• 12-18 months from Concept to Build (tentative)
 **Light Tactical** **14,000 - 16,000 lbs** 	• FED Program–OSD Funded • 30% Fuel Economy Improvement over M1151 • Maintain Mobility of M1114	• RICARDO • WTSI – Global Services	• 12 month Tech Discovery phase • 18-24 months from Concept to Build
	• MRAP Threshold Survivability • <14,000 lbs Vehicle Weight • System Cost of $250,000	• HARDWIRE – Composite Armor Systems	• 12 months from Design to Build

RDECOM will rapidly develop platform designs and demonstrators driving innovation in the areas of ground platform survivability and mobility

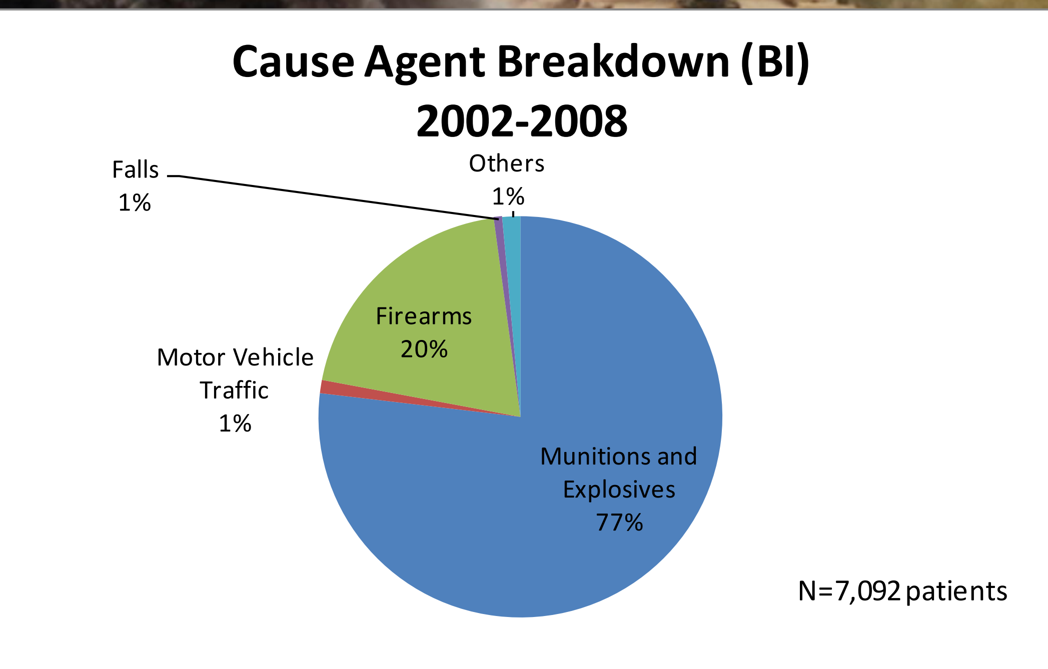
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

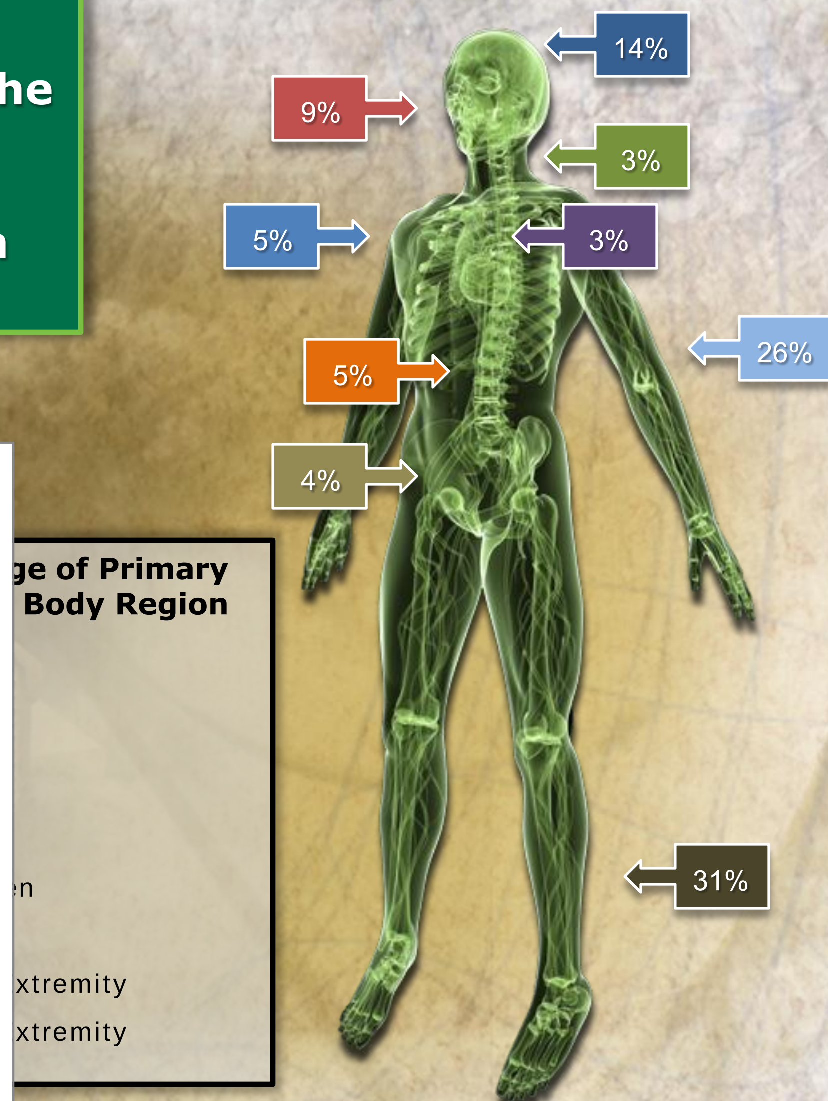
Risa Scherer
Team Leader- Blast Mitigation Team
Ground Systems Survivability
26 OCT 2010

What's the Issue?

Current Force Vehicles, although Survivable, have been designed from the outside in.

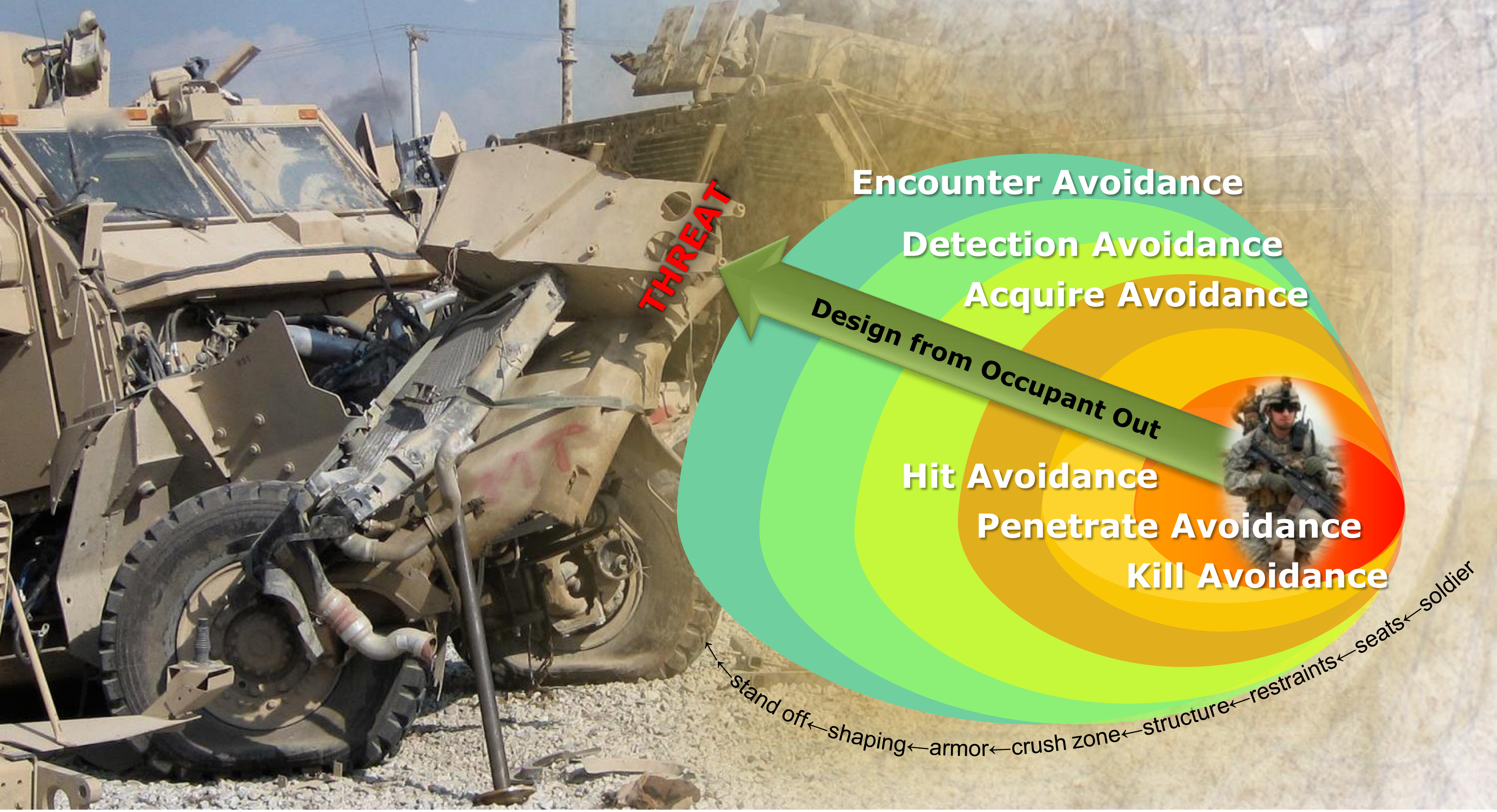
The Threat has Changed....our design philosophy has to change





New Design Philosophy

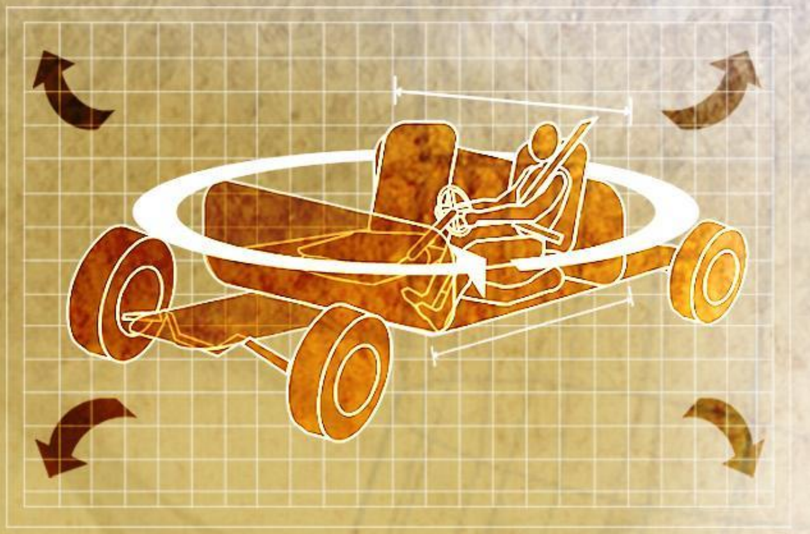
Occupant Centric Survivability



Designing from the Inside Out

Outside In

Inside Out



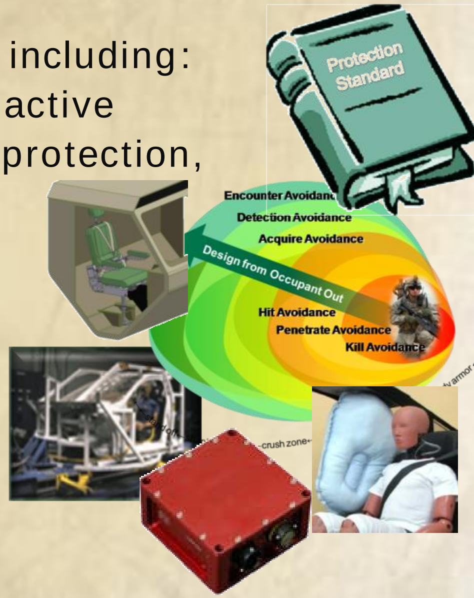
Occupant Protection Drives Vehicle Design

Occupant Centric System Integration Mission

- Provide superior customer support in the field of mine blast/IED and crash/rollover Occupant Protection technology Integration and Optimization and establish a state-of-the art laboratory to analyze the effects of System-Level component interaction

Occupant Centric Survivability Program

- PRODUCT:
  - Update/develop vehicle standards, models, and simulations for occupant protection against mines/IEDs
  - Build and test two integrated Occupant-Centric Survivability Technology Demonstrators
    - Demonstrate an ideal occupant compartment on a concept demonstrator
    - Integrate ideal occupant protection technologies onto a current force vehicle
  - Assessment and baseline of ground vehicles with respect to underbody blast/fragmentation
  - Develop/mature & spinout TRL 6 occupant protection technologies, including: Underbody mine/IED armor solutions, energy management seats, active restraints, air bags, event data recorder, extremity fragmentation protection, M&S support for effects due to blast and fragmentation etc.
- CUSTOMER:
  - All ground combat platforms
- TARGETED THREATS:
  - All Underbody Mine/IED Threats



RDECOM

What Does Occupant Survivability Entail?

TARDEC

- Occupant Survivability is:
  - The combination of many factors, including: vehicle weight, geometry (stand-off, hull shape), occupant protection technologies (seating, location false floor), charge size, and charge location, and how these factors interact with the crew member.
- Most effective protection for the occupants against the blast impulse is to decouple the occupants from the system structure.
- Design principles:
  - Decouple the occupant from the system structure
  - Divert blast energy away from the vehicle
  - Limit acceleration of the vehicle
  - Prevent breach of the vehicle
  - Limit the acceleration of the occupants
  - Protect the occupants from lethal debris
- Occupant Survivability needs to be designed in from the beginning, not as an afterthought… design from the inside out.

Current Capabilities

- RDECOM has one-of-a-kind “system level” underbody M&S capabilities that can be used for risk reduction for significant milestone decisions.
- Capabilities can be used for requirements definition and trade studies.
- Tools can be used to understand gaps between LFT&E events to increase confidence & decrease uncertainty in system capabilities & limitations.
- Can be run in series with Concept Refinement and Technology Development activities and parallel to System Development and Demonstration activities.

Technology Evaluation Methodology

- Physical Testing
  - Drop tower
  - Live fire
  - Ergonomic evaluation
- M&S Analysis
  - Obtain Technology and/or vehicle models
  - Correlate the model to test event
  - Parametric studies
    - Technology characteristics (mounting, geometry, material properties etc.)
    - Threat size and location
    - How it will be integrated into the vehicle
  - Prediction of LFT&E event
- Injury Assessment

Seating Programs

- Recent Seat Development Programs:
  - TWVS ATO Seat Selection
  - ASV Seating Modernization
  - MRAP Caiman RWS Seating
  - MRAP Remote Weapons Station Integration
  - MRAP RG31 Crew Seat Enhancement
- Current Seat Development Programs:
  - Cervigard Seat CRADA
    - Develop seat concept, FEA analysis, and sub-system level testing
  - NDCEE CRADA
    - Develop EA seating concept, FEA analysis, and sub-system level testing
  - ARC Testing
    - Desk top tool derived from testing seat parameters (materials, thicknesses, occupant sizes).

RDECOM

TWVS ATO Seat Selection

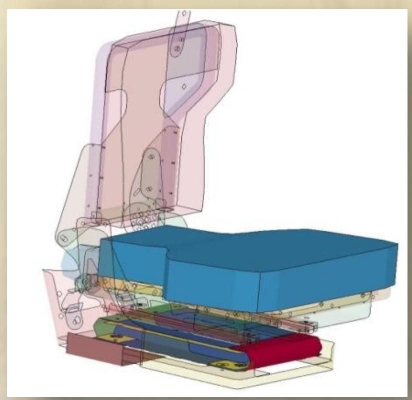
TARDEC

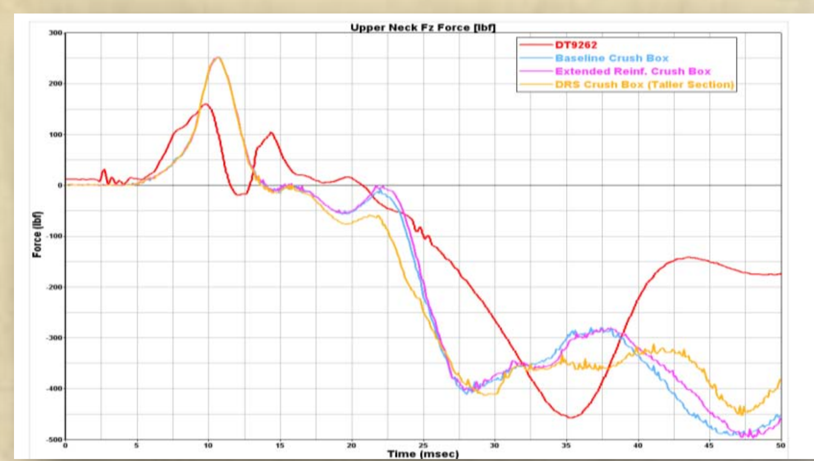
- Objective: Provide PM MTV a recommendation for the crew seat to be installed in the FMTV Integrated Survivability Demonstrator (ISD) and FMTV Ballistic Demonstrator (BALDEM) and receive concurrence on the path forward.
- The following seating candidates were evaluated using a combination of integration studies, cost analysis, modeling & simulation, and drop tower testing:
  - BAE Belts-to-Cab Seat
  - Martin Baker
  - Allen Vanguard
  - Armorworks Shockride
  - Isringhausen
  - GSS CCOOPPS Crush Box
  - Seats Inc.
  - Plasans/National Seating
  - Simula/Armor Holding
  - Mastercraft/Armor Holding

- The final candidate significantly reduced probability of pelvic, spinal, and lower extremity injuries for the driver. The results were verified in an overmatch under-wheel (driver's side) LFT&E event.

ASV Seat Enhancement

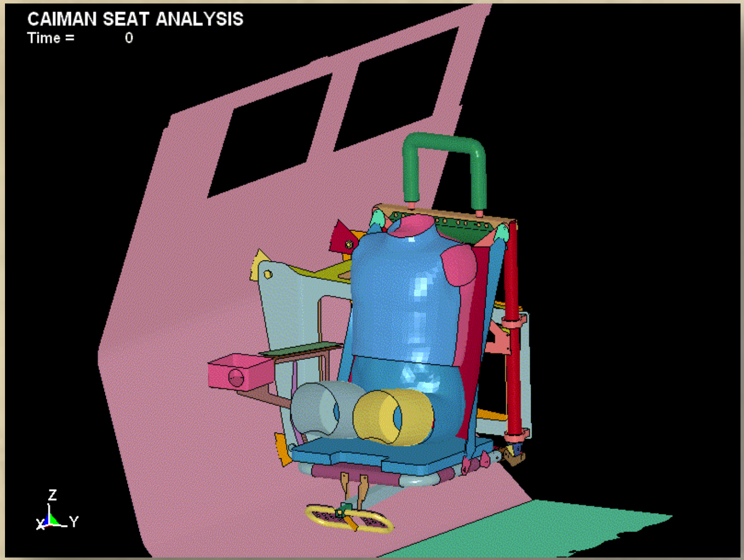
- Objective: Provide PM ASV a recommended crush box height and cushion thickness for their seating modifications. There was 130mm of available package space, and an optimized solution was required to balance comfort and blast mitigation.
- Modeling & Simulation
  - The finite element seat model was correlated to a series of drop tower tests
  - A series of parametric analyses were run using several variables for the crush box against the competing variable of cushion thickness.
- The analysis showed that a height reduction to 40mm and reconfiguration of the crush-box would actually perform better than the initial direction provided by the PM (60mm).
- PM ASV is currently in the process of fabricating and testing the prototypes of the final configuration.





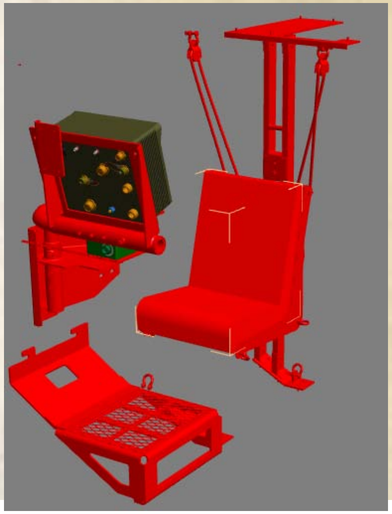
MRAP Caiman RWS Seating

- Objective: Provide an analysis for the reorientation of the Remote Weapons Station (RWS) seating location for the MRAP Caiman PM.
- Modeling & Simulation:
  - A correlated model of the Caiman was already available from previous analyses.
  - A design of the bracket for seat mounting was provided by the PM.
  - Evaluated a worst-case (95% male, full PPE) and best-case (5% female, standard PPE).
  - Plastic strain and effective stress on the mounting bracket were evaluated to ensure the material thresholds were not exceeded.
- The mounting bracket did not exceed the stress or strain thresholds for the materials selected.
- The solution was fielded with a minimum of physical testing and quicker turn-around-time.
- TARDEC also provided additional feedback relative to improvements in the Energy Absorbing (EA) mechanism and the integral footrest.



MRAP Remote Weapon Station (RWS) Occupant Seat Integration

- Several MRAP variants to be integrated with RWS; seats and footrests need to be rotated to face forward and maintain the same survivability performance
  - Existing seat, existing mount points on vehicle and seat
- TARDEC GSS and CASSI Analytics
  - Decomposed existing seat
  - Added new bracket developed in-house to mode
  - Computationally reconstructed past MRAP tests in both the current and RWS-integrated configurations.



» Determined that new bracket design would most likely not fail and occupant impact protection was not significantly impacted

» Model is currently being refined – seat contractor CAD provided, impulses verified, occupant weights updated to represent test configuration

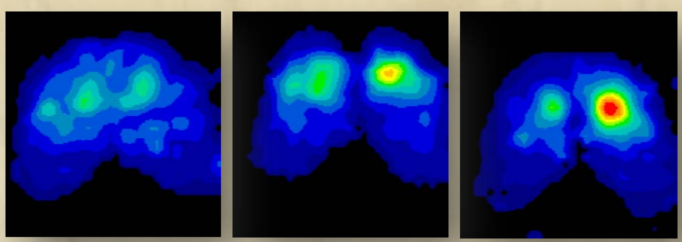
» Reduced the need to retest full vehicle

MRAP RG31 Seat Enhancement

- Objective: Evaluate two seat concepts (XBOX 1 and 2) that were developed to address severe spinal injuries being seen in theater.
- TARDEC Engineering Approach:
  - CAD and finite element models were generated from the paper concepts.
  - Parametric M&S analyses were run to determine the optimum parameters for the designs.
  - Prototype parts were fabricated from the optimized design.
  - Drop tower testing of the prototypes were compared to the baseline seat, as well as a field of approximately 20 other seat concepts and COTS solutions, using the following equation:

$$\left(\frac{Pelvis_{AZ}}{A_{critical}} + \frac{Spine_{Fz}}{F_{critical}}\right) * \frac{1}{\max AZ_{input}} * T_{\max Pelvis_{AZ}} * 1000$$

  - A static and dynamic comfort evaluation of the top candidates was also performed by TARDEC.



- The top three candidates were provided to PM MRAP for further consideration. Neither of the XBOX solutions were finalists.

Underbody Programs

- Recent Underbody Development Programs:
  - Tactical Wheeled Vehicle Survivability Underbody Kit Development
- Current Underbody Development Programs:
  - HEMTT Support
    - Develop
  - Joint Light Tactical Vehicle (JLTV) Support
    - M&S support to predict / validate vendor underbody performance
  - Combat Vehicle Armor Development (CVAD) ATO support
    - Provide a best practice guide on underbody design (standoff, geometry, material, etc.)
  - Lockheed Martin & Fire Control
    - Test Lightweight Titanium Protected Crew Compartment
  - Zero-G
    - Proof of Concept to decouple the crew floor and increase occupant survivability
  - Generic Hull Testing
    - Releasable (to the general public) test data on hull testing and ATD resulting injuries
  - HMMWV V-Hull
    - Virtually integrate and validate blast performance

TWVS ATO Demonstrator Underbody Kit (U-Kit) Development

- Requirement for upgraded underbody protection on TWVS ATO Demonstrator
- Partnership with TARDEC GSS, ARL/WMRD, TARDEC CASSI, Letterkenny Army Depot
- Physical and computational analysis
  - Space claim under and inside vehicle
- U-kit was modeled
  - Existing cab, existing appurtenances
- … And Tested
  - Prototypes were attached to representative hull/chassis, mine tested at ATC

- U-kit for TWVS ATO Demonstrator provides increased underbody protection

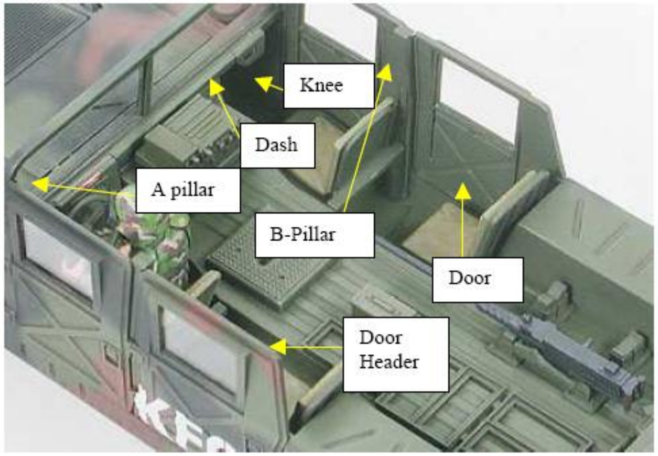
Interior Technologies

- Recent Programs:
  - Interior Appliqué for the TWVS Demonstrator
- Current Programs:
  - Air Bag / Restraint Technologies
    - TK Holding CRADA
      - Develop a suite of restraints and airbags to decrease occupant injury during a blast, IED, or crash event
  - Vehicle Data Recorder
    - Integrate DTS Transient Shock Recorders into currently fielded vehicles, upgrade existing COTS systems, and data analysis infrastructure
  - ATD Development
    - Perform cadaveric testing to characterize and develop a test dummy designed for the vertical loading seen in blast and IED events.

Interior Appliqué for TWVS ATO Demonstrator

- Leverage existing Phase II SBIR – Texas Research Institute, Austin
  - Expanded polypropylene w/ polyurea coating
  - Reduces blunt trauma injury to occupants
- Additional funding added to contract to develop prototype kits in support of TWVS ATO Demonstrator
  - Provide vehicle CAD to contractor
  - Determine high risk points for blunt trauma in vehicle
  - Utilize existing high heat testing at TARDEC to verify appliqué attachment
- Appliqué kit on TWVS ATO Demonstrator FY 10 full-scale testing

Material is unaffected by salt water!



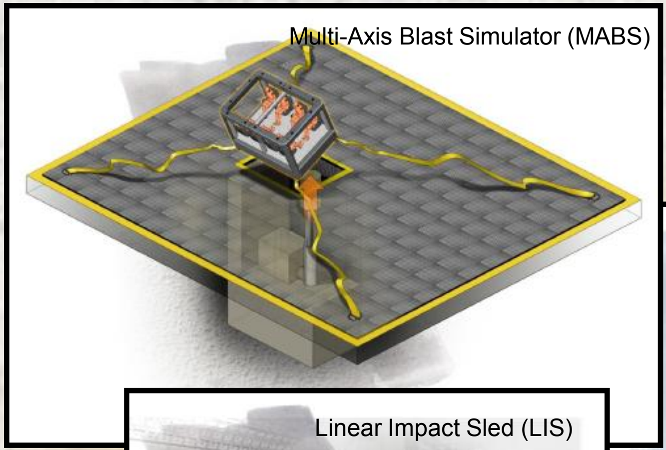
Vehicle Data Recorder System – "Black Box"

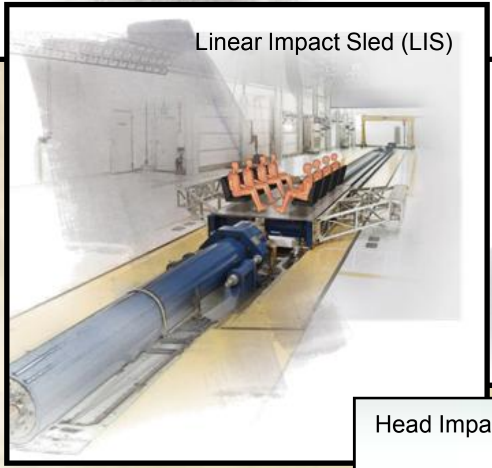
- Blast/IED Event Data Recorder System:
  - Gaps exist in data collected in theater
    - Accurate post blast/crash data collection techniques and recording equipment do not currently exist
    - Without full understanding of the blast/crash events, countermeasures cannot be optimally designed and integrated
  - Limiting Factors:
    - Accurate determination of the causative effects of injuries to the Warfighter
    - Understanding of injury mechanisms within operational context
    - Materiel/training solution development
    - Situational awareness of threat type and vehicle performance
  - This directly supports:
    - Development of test procedures and resultant countermeasures to protect the Warfighter
    - Accident and combat event investigations
    - Gathering information for vehicle diagnostics and prognostics
    - Refine and improve Tactics Techniques and Procedures (TTP)

Tri-axial accelerometer, angular rate and pressure sensor

Critical data is unobtainable unless collected in real-time

Occupant Protection Systems Integration Laboratories


Multi-Axis Blast Simulator (MABS)


Linear Impact Sled (LIS)


Vertical Impact Tower (VIT)


Head Impact Protection (HIP)

Purpose: The OP SIL provides the mechanism to evaluate, optimize, integrate, and validate occupant centric survivability and safety systems to mitigate injury due to blast and crash events.

Products:

The test equipment simulates blast & crash events and evaluates the occupant and protection system response to these forces.

- MABS: Underbelly blast events at system level
- LIS: Front & side impact, side IED, and rollover
- VIT: Vertical forces and floor deformation
- HIP: Head protection systems

Payoff:

MABS
- State-of-the-art unique piece of test equipment
- Reduced number of LFT&E (~LFT&E $75,000 - $150,000; MABS ~$15,400)

LIS
- Multiple crash events evaluated on one test device
- System design optimization for multiple impacts

VIT
- Assess multiple occupants & lower extremity injury
- Configurable platform - vehicle specific layout

HIP
- Low cost, quick assessment of a head impact protection
- Assess interior padding solutions

Conclusion

- Occupant Survivability needs to be designed in from the beginning, not as an afterthought… design from the inside out
- Occupant Survivability is a complex issue that involves many technologies optimized for each unique system